

Structural Relationships across the Lambian Unconformity in the Hervey Range-Parkes Area, N.S.W.

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Detailed mapping of the structural relationships in four areas on the flanks of the Hervey and Parkes Synclines shows that the angular discordance between Silurian and Lower Devonian rocks and the overlying Hervey Group is very low in the north and increases southward. Comparison of the structural style of the Hervey and Parkes synclines with synclines in rocks of similar facies from other areas in the northern Lachlan Fold Belt shows that the latest Devonian to Early Carboniferous folding is less intense in the Hervey Range-Parkes area than in the eastern Lachlan Fold Belt, but more marked than the gentle warping further west. Mid-Devonian folds in the Hervey Range-Parkes area, if present, were open to gentle, and trended north-northeast.

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INTRODUCTION

The Lambian Unconformity (Powell and Edgecombe, 1978, p. 166) in the northern Lachlan Fold Belt separates an upper well-bedded, quartzose, terrestrial to shallow-marine succession of sandstone and conglomerate from a lower succession that varies from graded-bedded sandstone and shale to massive silicic volcanics and granitic rocks. The lower parts of the quartzose upper succession, variously known as the Lambie, Catombal, Hervey, Cocoparra and Mulga Downs Groups in the northern Lachlan Fold Belt (Conolly, 1965, 1969) range in age from latest Early or early Middle Devonian in the basal Mulga Downs Group (Ritchie, 1973) to Late Devonian in the lower marine part of the Lambie Group (Roberts *et al.*, 1972). The upper parts of the succession may well extend into the earliest Carboniferous. The underlying rocks vary in age depending on the lacuna across the unconformity; in places, they are Early Devonian and elsewhere are as old as Ordovician.

The structural relationships across the Lambian Unconformity have been mapped to determine the relative importance of deformations before, and after, deposition of the quartzose succession (Powell and Edgecombe, 1978; Powell and Fergusson, 1979a,b). By considering areas where the underlying rocks are no older than earliest Devonian, or, if older, where they can be shown to be conformable into the earliest Devonian, the relative importance of mid-Devonian and latest Devonian to Early Carboniferous deformation across the Lachlan Fold Belt may be compared.

Mechanically, the upper quartzose succession is less ductile, and has a higher ductility contrast, than most of the underlying rocks, with the exception of areas of granite and multiply-deformed volcanics that may act as rigid masses in subsequent deformations (e.g. the Ordovician Sofala Volcanics, Powell *et al.*, 1978). The

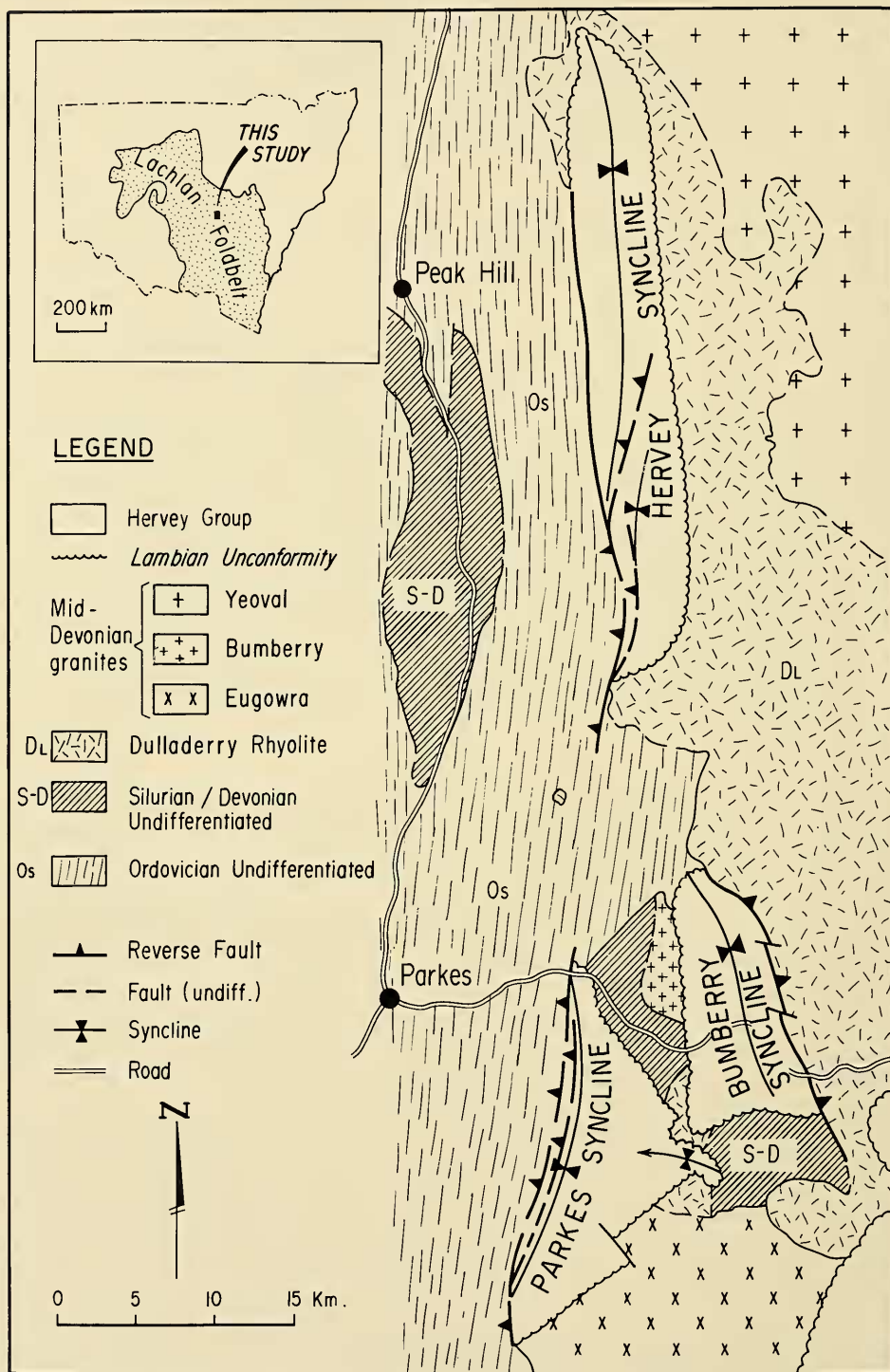


Fig. 1. Structural setting of the Parkes and Hervey Synclines.

quartzose succession can thus be expected to deform into cylindrical concentric folds by layer-parallel slip while the underlying rocks may deform in several ways including forming conical folds with the same general trend but varying vertex angles depending on the pre-fold attitude of the beds (Haman, 1961; Ross and McGlynn, 1963; Stauffer, 1964; Ramsay, 1967).

In this paper, the relationship of structures across the Lambian Unconformity is described from the Hervey and Parkes Synclines in the central-northern Lachlan Fold Belt (Fig. 1). The broad stratigraphy of the quartzose succession was described by Conolly (1965), and the southern part of the area has been mapped in greater detail by Williams (1975).

GEOLOGICAL SETTING

The oldest rocks known in the region (Fig. 1) are Ordovician, consisting of thinly-bedded quartzose sandstones and slates of flyschoid aspect which overlie andesites, limestones and interbedded marls west of Parkes (Packham, 1969). This sequence is overlain unconformably (?) by an Upper Silurian (?) to Lower Devonian succession of lithic sandstones and shales, with interbedded massive to foliated, porphyritic, silicic volcanic rocks. In the mapped area, two units of the Upper Silurian (?) to Lower Devonian succession occur, the Dulladerry Rhyolite and an informal unit of shales and interbedded feldspar-lithic graded sandstone, the 'Moura beds'. The 'Moura beds' are typically olive grey silts and shales in which sporadic influxes of coarse detritus have produced thick sandstone units. Flute marks on the base of 6 sandstone units indicate an average direction of flow towards 355° , and the mean of 5 occurrences of tool marks on the soles of sandstone beds gives a line of current 018° or 198° . Outcrops on the eastern side of the Parkes Syncline indicate that the Dulladerry Rhyolite and the 'Moura beds' are either interbedded or in fault contact. Further east (GR 1493 8838, Bathurst 1:250,000 geological sheet) marine sediments conformable below the Dulladerry Rhyolite have yielded fossils of Early Devonian, probably late Lochkovian age (Pickett, 1979).

The 'Moura beds' are intruded by the Eugowra and Bumberry Granites and associated rhyolite dykes. The relationship of the Dulladerry Rhyolite to the Eugowra Granite is not clear, because although both occur in close proximity on the southeastern side of the Parkes Syncline, the contact relationships are not exposed. The Dulladerry Rhyolite, which includes a variety of rocks ranging from lenticular tuff, banded rhyolite, basalt and water-laid clastics to porphyry, may well be the surface equivalent of the subjacent contemporaneous granite. All these rocks are overlain by the Hervey Group which can be subdivided (Conolly, 1965) into a thin, lower, arkosic to lithic unit of sandstone, siltstone and red mudstone (Beargamil Sub-Group), a thick, middle, cyclic sequence of cross-bedded quartzite, minor conglomerate, and interbedded red siltstones and shales (Nangar Sub-Group), and an upper thick unit of red siltstones and mudstones (Cookamidgera Sub-Group). The relative stratigraphic order (legend, Fig. 1) is consistent with the 1:250,000 Narromine and Forbes geological maps (Brunker, 1967, 1968). No relative ages have yet been established between the Yeoval, Bumberry and Eugowra Granites.

The Ordovician rocks are in contact with the Hervey Group along the western limbs of the two synclines, separated by high-angle reverse faults. On other limbs of these synclines the Hervey Group rests unconformably on various older rocks, the angular discordance (described below) increasing southward. The regional structure trends meridionally, but there are folds, faults and airphoto lineaments trending obliquely.

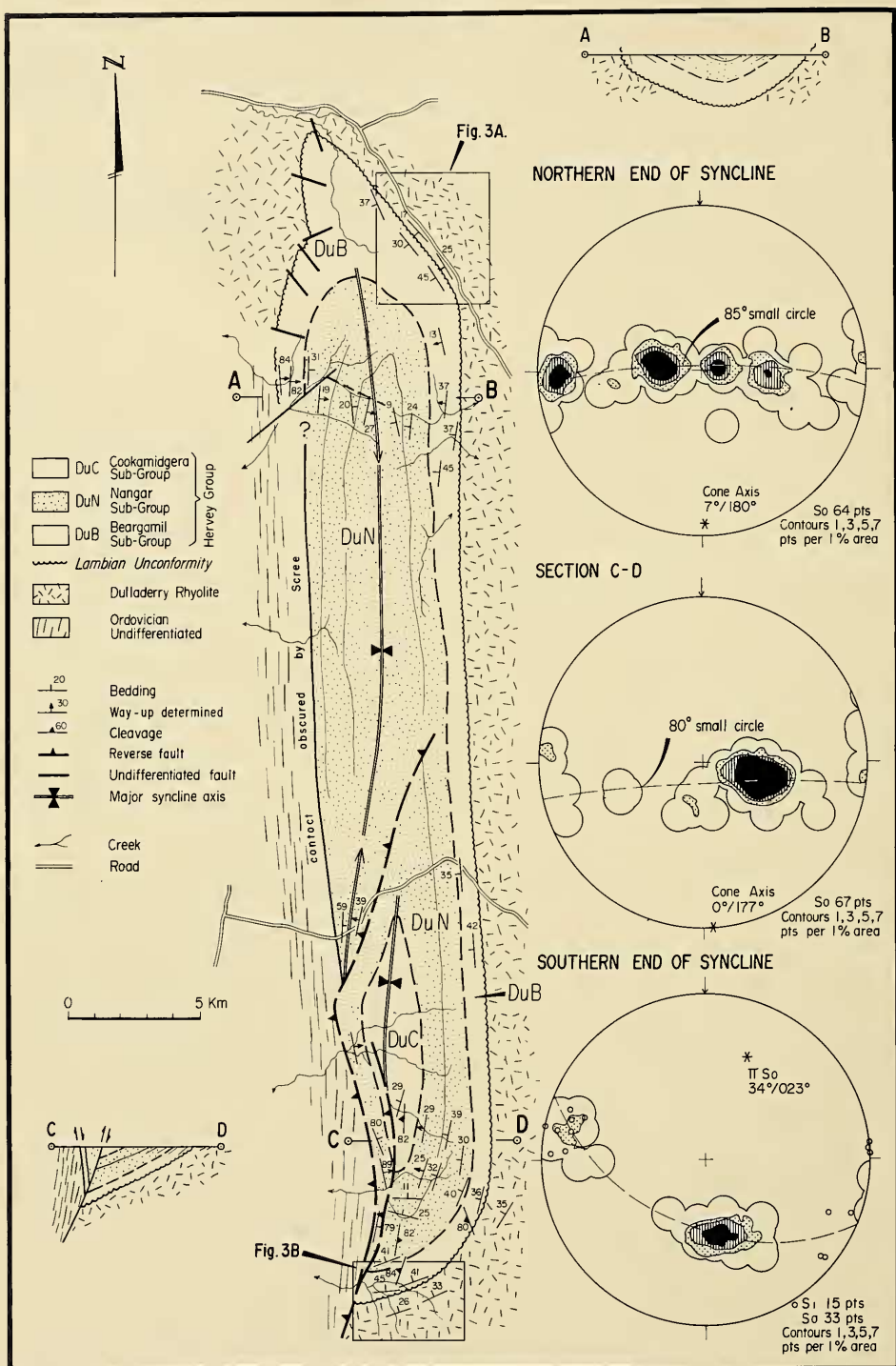


Fig. 2. Structure of the Hervey Syncline. Geological contacts plotted on enlarged air-photo mosaic base. A-B and C-D are natural-scale cross sections.

STRUCTURE

Hervey Syncline

The Hervey Syncline consists of two en-echelon synclines separated by a north-northeasterly trending fault that cuts obliquely across the meridional trend (Fig. 2). Conolly (1965, p. 47) considered the fault to be normal with the southeastern side down-thrown, but there is no conclusive evidence of which way the fault dips. In Fig. 2, the fault is depicted as a continuation of the high-angle reverse fault along the western margin of the southernmost syncline.

Profiles through the Hervey Syncline vary from open in the north (interlimb angles of 105° and 130° for Conolly's (1965) fig. 7, sections A-B and C-D respectively, but 60° if the nearly vertical beds on the western part of our section A-B, Fig. 2, are taken into account) to close in the south (interlimb angles of 56° for section E-F, Conolly (1965, fig. 7), and 61° in our section C-D, Fig. 2). There is no cleavage in the

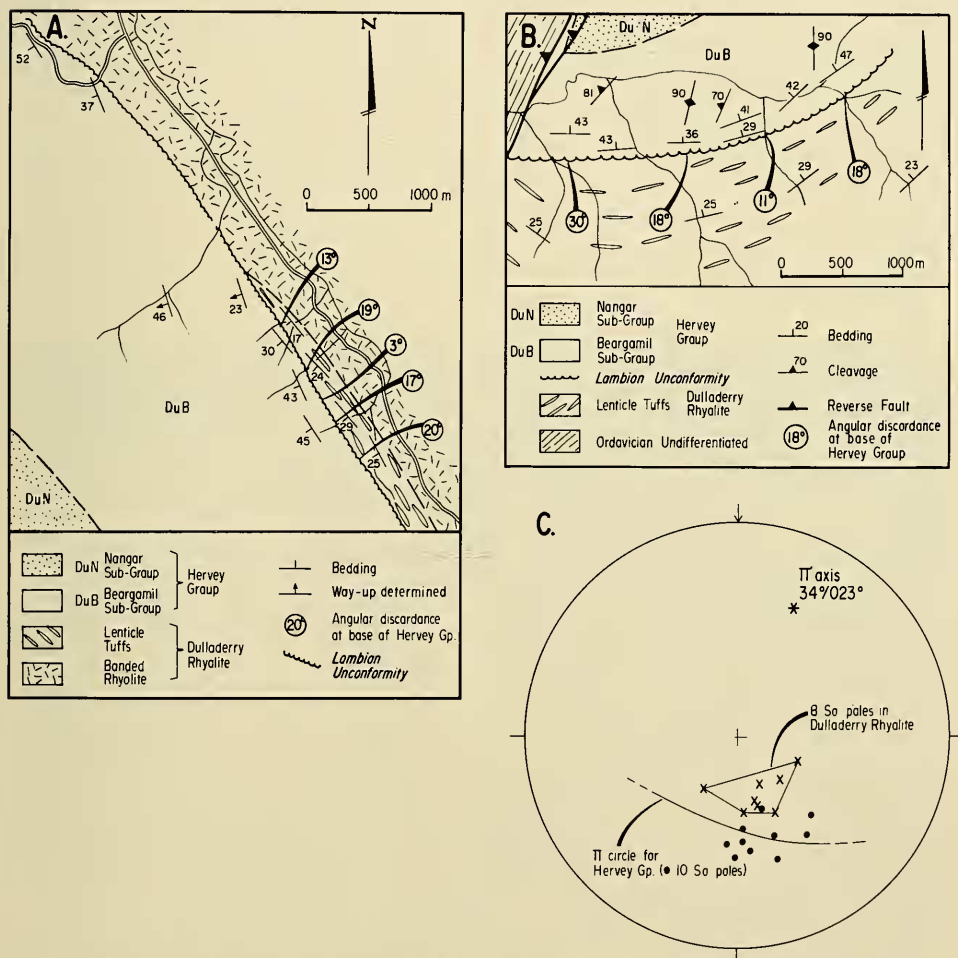


Fig. 3. A. Detail of structural relationships across the Lambian Unconformity at the northern end of the Hervey Syncline. B. Detail of structural relationships across the Lambian Unconformity at the southern end of the Hervey Syncline. C. Stereogram of bedding poles in the Dulladerry Rhyolite and adjacent Hervey Group from the area in B. π -circle for Hervey Group is extrapolated from Fig. 2.

Hervey Syncline except at the southern end where a statistically planar, anastomosing, disjunctive cleavage (Powell, 1979) spaced at cm-scale and parallel to the steep, westerly-dipping fault bounding the western limb, pervades the quartzites and conglomerates.

Equal-area stereograms of bedding poles from the Hervey Group along sections A-B and C-D give small-circle patterns that correspond closer to conical patterns (stereograms in Fig. 2) than to cylindrical distributions. The cone axes are nearly horizontal, and in both cases the cone apex points southward. This relationship can be explained in both areas by the tightening of the fold profile southward. In the northern section the fold profile tightens towards the middle of the syncline, culminating in the displacement on the north-northeasterly trending fault. In the southern section, the fold profile tightens towards the south of the fold as increasing displacement is taken up on the flanking high-angle reverse fault. In the southern part of the Hervey Syncline a wedge of Nangar Sub-Group lies between two splays of the western bounding fault, and the bedding in this wedge gradually steepens southward until it is vertical. The extreme southern end of the syncline, where there is the platy, disjunctive cleavage, plunges appreciably more steeply (34° towards 023°) than other parts of the fold. Because of the lack of a regional axial-surface cleavage, the orientation of the axial plane can be approximated only by inspection of the attitude of the fold limbs which dip more steeply (60° to 90°) on the west than on the east (35° to 45°). The axial plane is thus probably inclined steeply west at between 70° and 75° .

The orientation of bedding in the rocks below the Lambian Unconformity has been determined in two areas, at the northern and southern ends of the syncline. Elsewhere, outcrop is poor or bedding is absent in the Dulladerry Rhyolite. In the northern area (Fig. 3A), a band of lenticle tuff (Fig. 4) overlies banded rhyolite, and

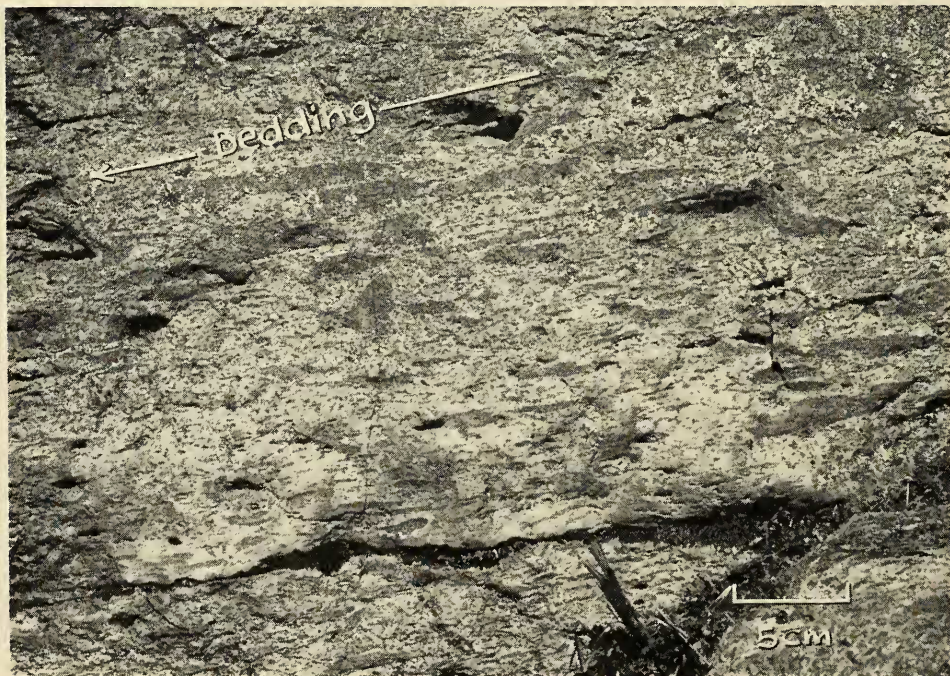


Fig. 4. Lenticle tuff immediately below the Lambian Unconformity at northern end of Hervey Syncline (Fig. 3A).

the outcrop pattern shows a low-angle erosional truncation of the lenticle tuff by the Hervey Group. Five bedding couplets across the Lambian Unconformity give an angular discordance ranging from 3° to 20° , with a mean of 14° , which, considering the inherent inaccuracies (Powell and Edgecombe, 1978, fig. 2), is a very low-angle truncation.

Another band of lenticle tuff in the Dulladerry Rhyolite at the southern end of the Hervey Syncline allowed us to determine four more angular discordances across the Lambian Unconformity (Fig. 3B), with a range of 11° to 30° and a mean of 19° . These individual calculations of the magnitude of the angular discordance agree well with the average angular separation shown by the cluster of eight bedding poles from the lenticle tuff in the Dulladerry Rhyolite as compared with the π -circle distribution of the immediately adjacent basal Hervey Group (Fig. 3C).

Parkes Syncline

The Parkes Syncline has a triangular plan shape with the longest side trending meridionally (Fig. 5). The structure is markedly asymmetric, with steep to locally overturned dips in the western limb. A system of high-angle reverse faults is parallel to, and truncates part of, the western limb, as in the Hervey Syncline. The eastern limb has moderate to gentle westerly dips (commonly 20° to 49°) though in the northern end dips steepen to more than 80° . A gentle synclinal, crossfold near Mt. Bolton plunges shallowly to the west-northwest.

Latitudinal profiles through the Parkes Syncline vary from close to tight (interlimb angles of 24° and 66° in our sections A-B and C-D, Fig. 5, respectively, and of 66° in Conolly, 1965, fig. 9), with the thickness of the western limb attenuated by movement on high-angle reverse faults dipping westward. The axial surface dips steeply westward, but its precise attitude cannot be determined from bedding data alone. Equal-area stereograms of bedding poles from the northern and southern ends of the syncline reflect the curved, inward-plunging fold axis which, at the northern end, plunges steeply (60° towards 170°). A meridional profile across the shallowly west-northwesterly plunging cross-fold at Mt. Bolton is gentle (interlimb angle around 130°). There is no axial-surface cleavage.

The rocks below the Hervey Group across the Lambian Unconformity include the well-bedded 'Moura beds', the massive Dulladerry Rhyolite and the Eugowra Granite on which the Hervey Group rests nonconformably. The best exposure across the Lambian Unconformity occurs in the Mt. Bolton area (Fig. 6) where, in at least one outcrop, the contact is exposed (Fig. 7). The structure of this area has been mapped in detail, and as well as 16 separate calculations of the angular discordance (Fig. 8A; range from 26° to 97° , with a mean of 42°), the gross structure of the 'Moura beds' has been outlined by walking out several prominent lithic sandstone units (Fig. 6).

Equal-area stereograms of bedding poles in the Mt. Bolton area reflect divergent fold axes across the unconformity (Fig. 9). Bedding in the Hervey Group defines a gentle fold plunging 8° towards 287° (Fig. 9A), whereas bedding in the immediate underlying 'Moura beds' lies on a 70° -small circle about a cone axis plunging 55° towards 001° (Fig. 9B). The trend of the cone axis is parallel to the regional meridional structure, and the 70° -small circle is probably caused by the dip the 'Moura beds' had before the Hervey Group was deposited. The reason for the steep plunge of the cone axis, however, is not clear.

There is no cleavage parallel to the meridional cone axis, but a local cleavage trending 070° to 080° is developed in the Hervey Group (as a platy to anastomosing disjunctive cleavage, spaced at the cm-scale) and in the 'Moura beds' (as an anastomosing, reticulate cleavage in mudstones) around Mt. Bolton at the eastern end

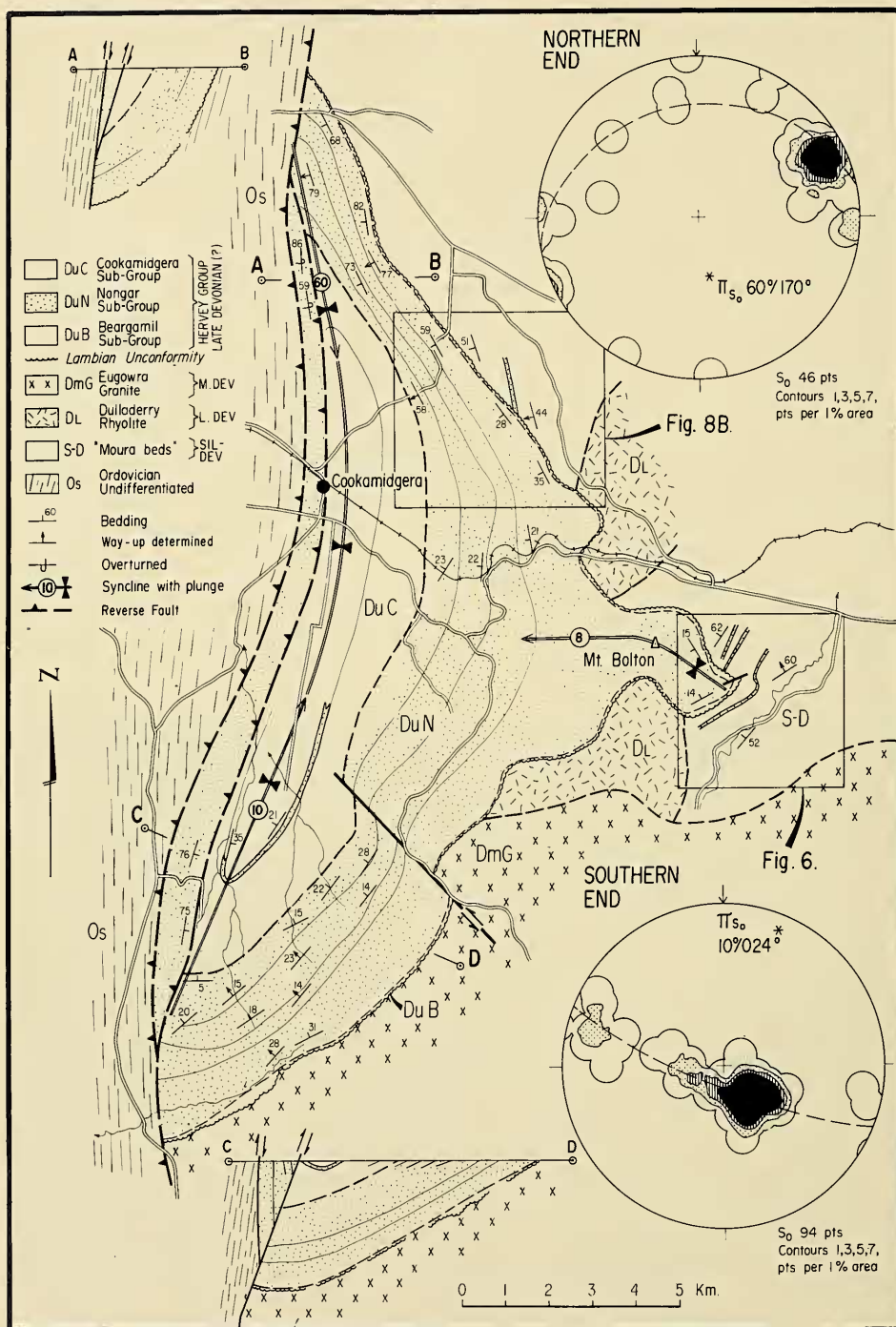


Fig. 5. Structure of the Parkes Syncline. Geological contacts plotted on enlarged air-photo mosaic base. A-B and C-D are natural-scale cross sections.

of the Parkes Syncline. In this area, there are a number of small faults (one offsets the trace of the Lambian Unconformity in Fig. 6) and mesoscopic folds with the same east-northeasterly trend — a direction also approximately parallel to the outcrop trace of rhyolite dykes probably related to the Eugowra Granite. These east-northeasterly trending structures occur only in a 500-metre wide zone, and are superimposed on the regional meridional folds.

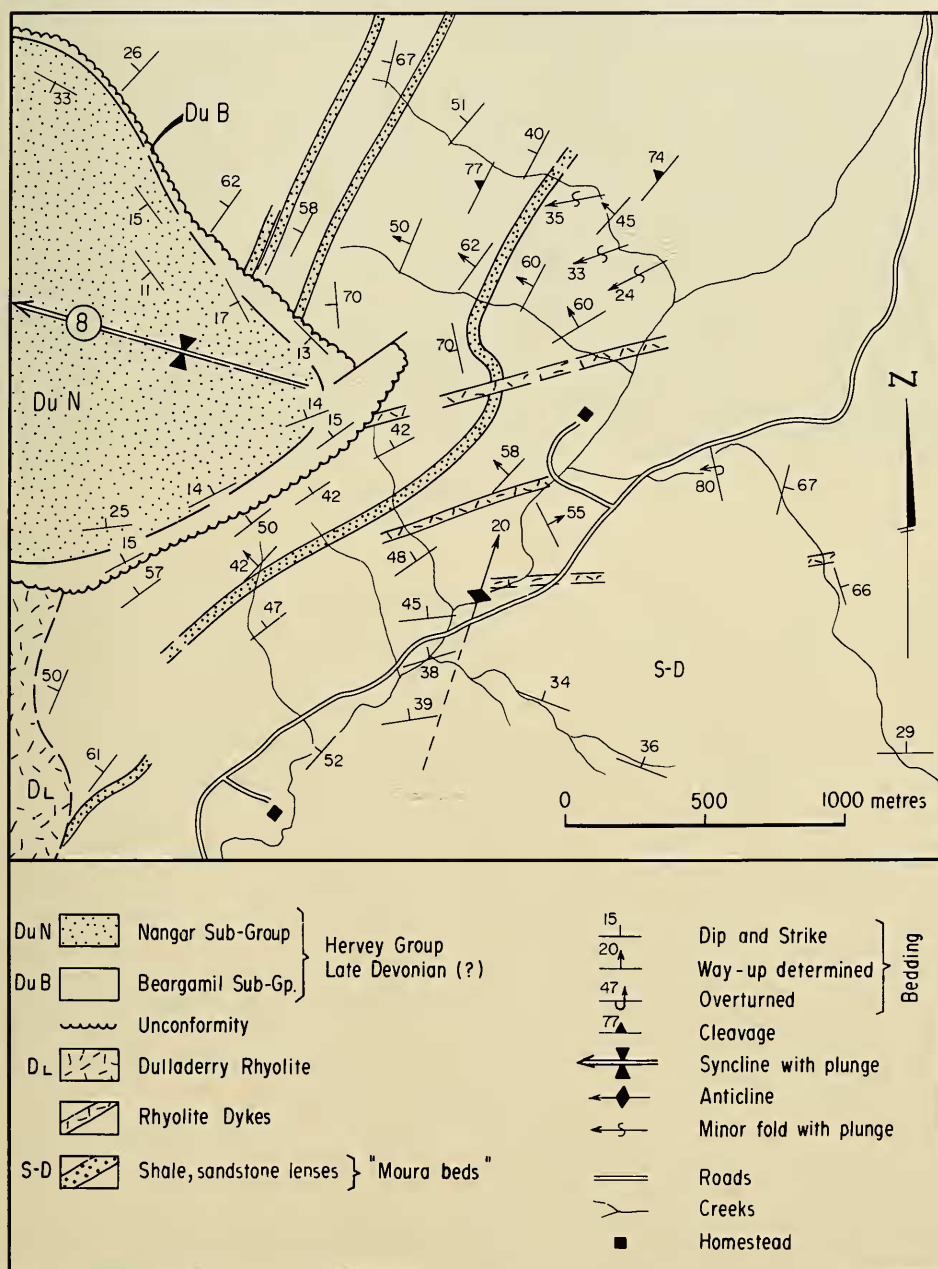


Fig. 6. Detailed structure of the Mt. Bolton area, at the eastern end of the Parkes Syncline.

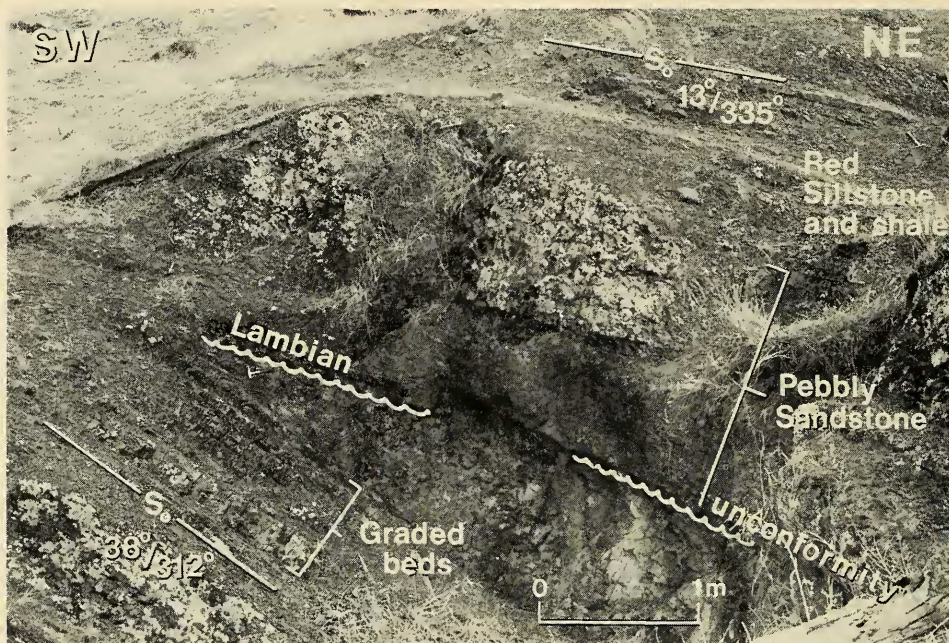


Fig. 7. Lambian Unconformity exposed on the southeastern side of Mt. Bolton (location in Fig. 8A). The underlying beds dip 38° towards 312° and the overlying beds dip 13° towards 335°.

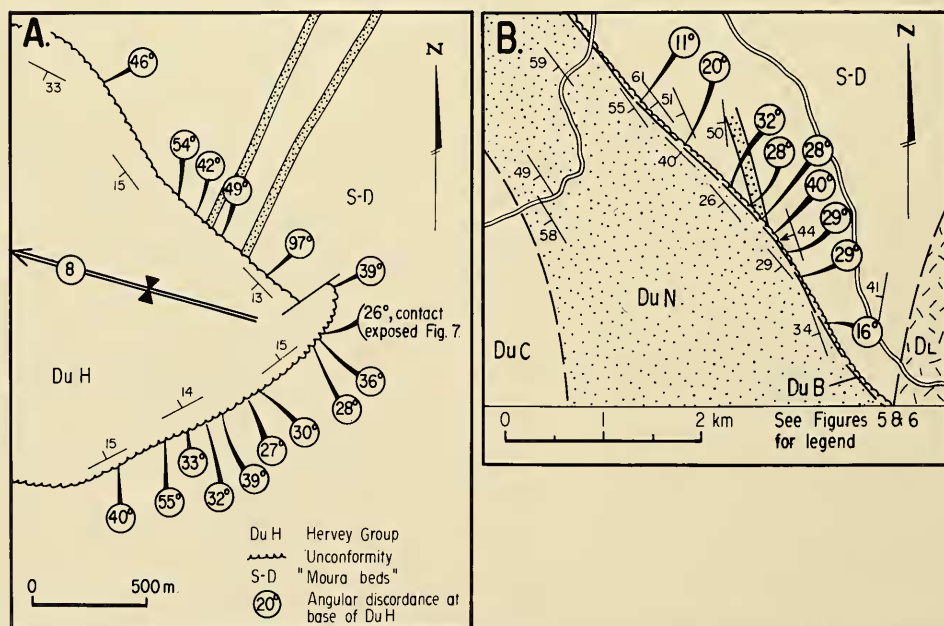


Fig. 8. A. Angular discordances across the Lambian Unconformity in the Mt. Bolton area (Fig. 6). B. Detail of structural relationships across the Lambian Unconformity on the northeastern flank of the Parkes Syncline (location in Fig. 5).

The structure of the underlying beds was also determined on the northeastern flank of the Parkes Syncline (Fig. 8B). In this area, nine bedding couplets across the Lambian Unconformity give an angular discordance ranging from 11° to 40° with a mean of 26° . A sandstone bed striking more northerly than the Hervey Group can be traced in the 'Moura beds' up to the Lambian Unconformity. A fault offset in the trace of the Lambian Unconformity on the southeastern flank of the Parkes Syncline (Fig. 5) suggests some brittle deformation of the Eugowra Granite after deposition of the Hervey Group.

DISCUSSION

Mid-Devonian bedding orientations

The bedding orientations in the 'Moura beds' and Dulladerry Rhyolite were restored stereographically to their presumed disposition prior to deposition of the Hervey Group using the local fold axes (method in Powell *et al.*, 1978). The resulting stereogram suggests a sub-horizontal pre-Hervey Group fold axis trending north-northeasterly (Fig. 10). No mid-Devonian fold hinges have been found so that the restored mid-Devonian bedding orientations may have been formed equally as much by simple tilting about a north-northeast axis as by regular folding about the same axis. The average pre-Hervey Group orientation of the beds in the Mt. Bolton area is a dip of between 40° and 60° towards 308° . This orientation is approximately 70° oblique to the later regional, sub-horizontal, meridional fold axis which may account for the 70° small-circle distribution of the bedding poles (Fig. 9B).

Angular discordance across the Lambian Unconformity

The 34 calculations of the angular discordance across the Lambian Unconformity in the Parkes-Hervey Ranges area appear to show a trend of increasing discordance southward (Fig. 11). Most of the discordances at the northern end of the Hervey Syncline are low enough to be caused by imprecision in the method of estimating the magnitude of the angular discordance (Powell and Edgecombe, 1978, fig. 2), but there does appear to be a gradual truncation of the 100 m thick lenticle-tuff horizon over more than 1.5 km along strike. The possibility of facies change over this distance, however, cannot be ruled out. The angular discordance at the northern end of the Hervey Syncline is thus very low, and possibly the Lambian Unconformity there is a paraconformity.

In the Mt. Bolton area, angular discordances around 40° are common. Present data do not permit us to determine whether the increase in angular discordance near Mt. Bolton is local, caused by tilting during mid-Devonian intrusion of the Eugowra Granite, or whether it is part of a regional trend of mid-Devonian angular discordance across the Lambian Unconformity increasing southward as noted in the eastern Lachlan Fold Belt (Powell and Edgecombe, 1978; Powell and Fergusson, 1979a,b). Angular discordances north of Bathurst are less than 30° , but increase southward along the Cookbundoon Synclinorium to exceed 90° locally, near Taralga. To the northwest, in the Cobar area, the contact between the Mulga Downs Group and the underlying Amphitheatre Group is essentially conformable, with only small areas of angular discordance that can be related to slumping and local folding in the underlying rocks (Glen, 1978, 1979). Such a pattern of mid-Devonian angular discordances increasing southwards in the Lachlan Fold Belt might be expected if there was an area of major mid-Devonian deformation in southern New South Wales and Victoria dying out northwards.

Another possibility exists if the 'Moura beds' are older than the Late Silurian to

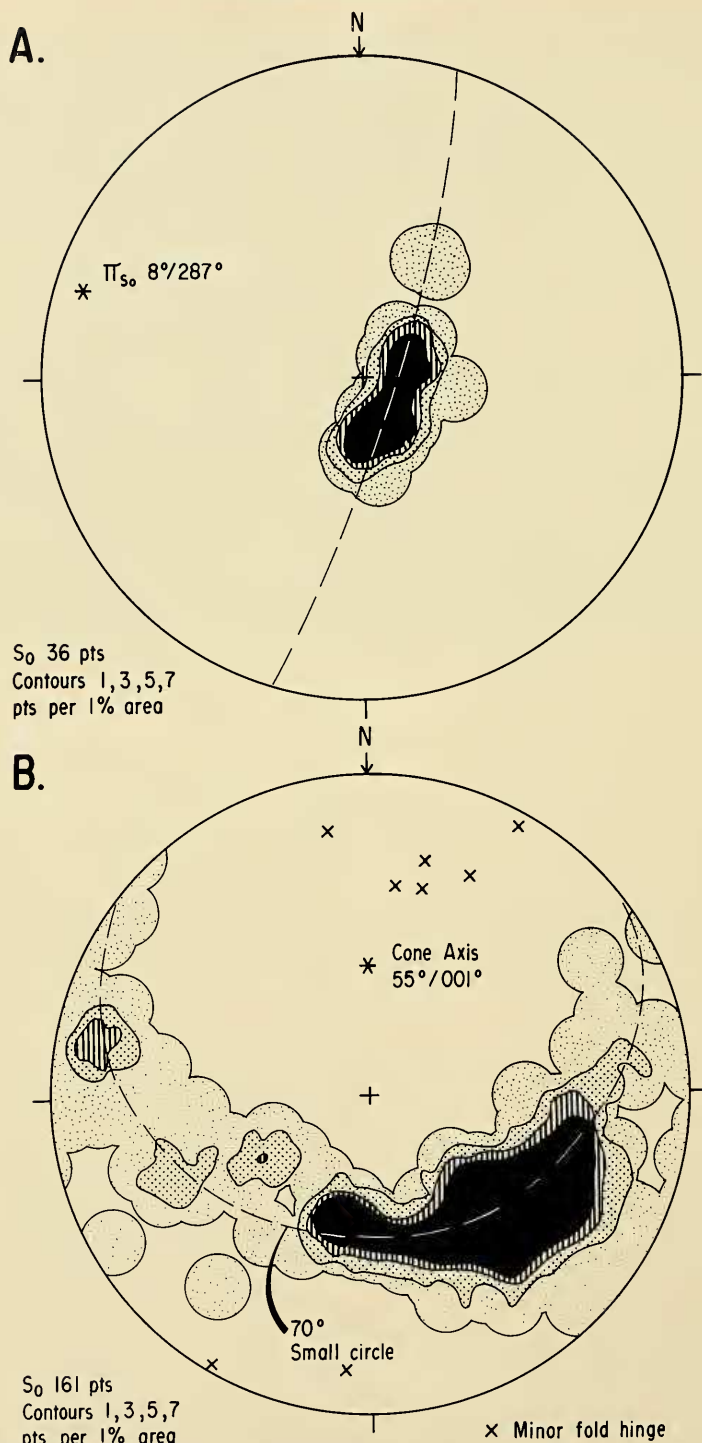


Fig. 9. A. Equal-area stereogram of bedding poles in the Hervey Group in the Mt. Bolton area (Fig. 6). B. Equal-area stereogram of bedding poles in the Moura beds in the Mt. Bolton area (Fig. 6).

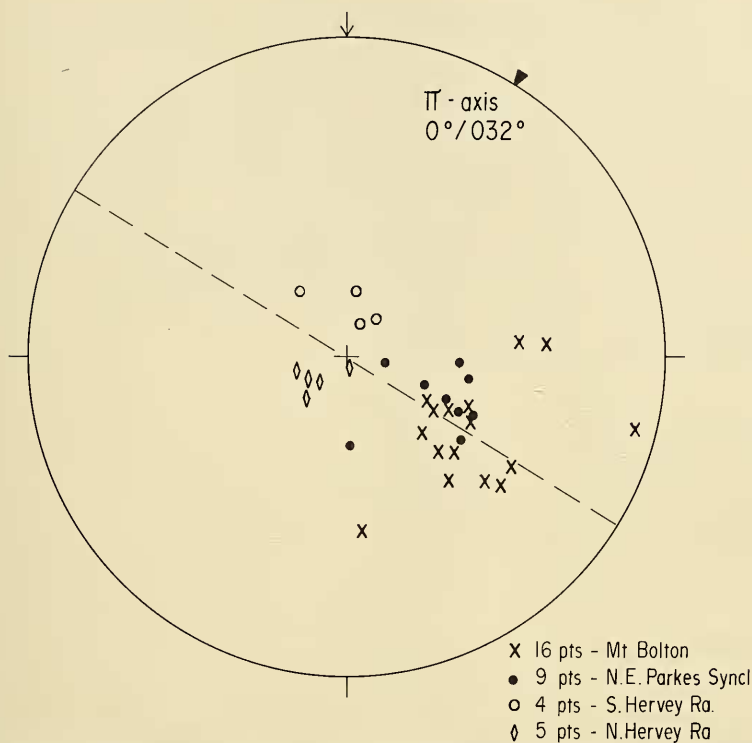


Fig. 10. Equal-area stereogram of mid-Devonian bedding orientations from the Hervey Range-Parkes area, after the overlying Hervey Group has been restored to horizontal stereographically using the procedure outlined in Powell *et al.* (1978).

Early Devonian age we have inferred, because then the angular discordance at Mt. Bolton may have been caused by movements older than mid-Devonian. In either case, the mid-Devonian deformation in the Parkes area was mild, and, if any folds developed, they were gentle to open in profile and trended north-northeast. No cleavage developed during the mid-Devonian deformation in the Parkes area.

Comparison of the post-Hervey Group deformation in the Parkes area with other areas

The structural style of the Hervey Group in the Parkes area is, in many ways, transitional between the relatively intense deformation in equivalent rocks in the northeastern Lachlan Fold Belt (Powell *et al.*, 1977; Powell and Edgecombe, 1978; Powell and Fergusson, 1979a) and the mild warping in equivalent rocks in the western part of the fold belt (Table 1, cf. Burns and Embleton, 1976). The meridional fold trends are quite well-defined in the Parkes area, although some oblique trends do occur (e.g. Mt. Bolton area). The fold profiles have interlimb angles in places as close as 60° — more open than the tight to isoclinal folds in the northeastern Lachlan Fold Belt, but much tighter than the gentle warps of the Cobar area. Axial surfaces are either upright or inclined steeply west, an orientation common in the northeastern Lachlan Fold Belt where there is a tendency for axial surfaces to dip more shallowly westward in the extreme east (Crook and Powell, 1976, fig. 7-4). In common with the northeastern Lachlan Fold Belt, the western limbs of synclines are commonly sheared out by high-angle reverse faults, although in the Bumberry Syncline (Fig. 1) a reverse

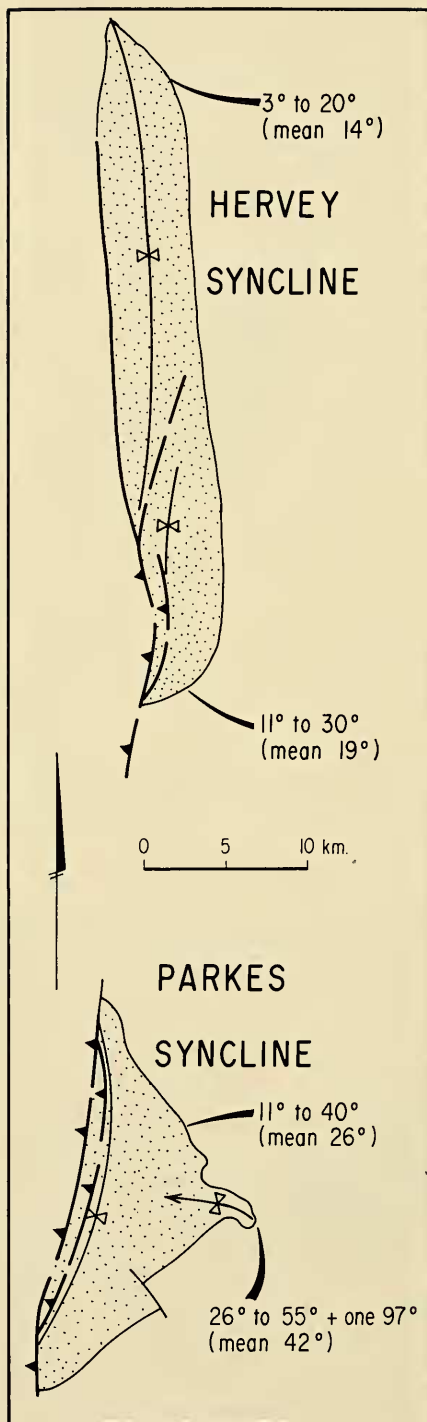


Fig. 11. Range and mean of mid-Devonian angular discordances across the Lambian Unconformity from the four areas in the Hervey Range-Parkes area.

TABLE 1
Comparison of structural style across the northern Lachlan Fold Belt in the Hervey Group
and equivalent facies

	Western area (Cobar)	Central area (Parkes)	Eastern area (Molong-Turon River)
Fold trends	Variable, with an overall north-northwesterly azimuth.	Grossly meridional with some oblique trends.	Strongly meridional trends.
Fold shape	Gently folded, centrocinal structures (domes, basins, noses and saddles).	Open to closely folded synclinal structures with rare anticlines.	Tight to isoclinally folded synclines.
Axial surface and fold symmetry.	Upright and symmetrical.	Upright to inclined steeply (70°) westward. Commonly asymmetrical with western limb sheared out.	Overturned to inclined, usually westward, at angles decreasing to 55° in the east.
Cleavage	Absent	Virtually absent, developed locally in areas of presumed high strain.	Widespread slaty type in pelitic units, with disjunctive, platy to anastomosing cleavage in conglomerates and sandstones in some places.

fault occurs on the eastern limb. Cleavage is virtually absent from the Parkes Syncline westward, but is quite well developed in the Murga area some 20 km east. In the northeastern Lachlan Fold belt, slaty cleavage is developed in pelitic units, and a platy to anastomosing, disjunctive cleavage, spaced at the cm-scale, is common in conglomerates and some sandstones.

These combined features suggest a westward dying-out of the latest Devonian to Early Carboniferous deformation in the northeastern Lachlan Fold Belt (Powell *et al.*, 1977). One possible explanation for this westward (also southwards) decrease in deformational intensity may be the different states of consolidation of the substrate on which the Lambie and equivalent facies rested during the later deformation. In the Parkes area, Early or Middle Devonian granites would have acted as rigid, or at least less ductile, bodies in comparison with the well-bedded flyschoid rocks of the northeastern Lachlan Fold Belt. It is possible that fractures which developed in the Parkes area prior to the deposition of the Hervey Group propagated upward during the later meridional deformation, thereby controlling local fold orientations. It is also possible that ductility contrast between the mid-Devonian granites and the surrounding flyschoid rocks produced strain heterogeneities that controlled the trends of local folds. Further work is required to test such hypotheses.

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